JOINT PHOTOGRAPHIC EXPERTS GROUP (JPEG) LOSSLESS IMAGE COMPRESSION PROFILE

FOR THE
NATIONAL IMAGERY TRANSMISSION FORMAT STANDARD

DRAFT

FOREWORD

1. The National Imagery Transmission Format Standard (NITFS) is the standard for formatting digital imagery and imagery-related products and exchanging them between members of the Intelligence Community (IC) as defined by Executive Order 12333, the Department of Defense (DoD), and other departments or agencies of the United States Government as governed by Memoranda of Agreement with those departments or agencies.

2. The National Imagery Transmission Format Standard Technical Board (NTB) developed this standard based upon currently available technical information.

3. The Department of Defense and members of the Intelligence Community are committed to interoperability of systems used for formatting, transmitting, receiving, and processing imagery and imagery-related information. This standard describes the Joint Photographic Experts Group (JPEG) lossless compression algorithm and establishes its application within the NITFS.

4. Beneficial comments (recommendations, additions, deletions) and other pertinent data which may be of use in improving this document, should be addressed to: TASC, 55 Walkers Brook Drive, Reading, MA 01867-3297, Attn: NTB Secretary, by using the pre-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

1. SCOPE

1.1 Scope. This document establishes the requirements to be met by NITFS compliant systems when image data is compressed using the JPEG lossless image compression algorithm as described in IS 10918-1, "Digital Compression and Coding of Continuous-tone Still Images."

1.2 Content. This document provides a profile of IS 10918-1 for the NITFS compression algorithm designated by the code C5 in the Image Compression field of the NITF file image subheader for 2 to 16-bit gray scale imagery and 24-bit color imagery.

1.3 Applicability. This standard is applicable to the Intelligence Community and the Department of Defense. It is mandatory for all Secondary Imagery Dissemination Systems in accordance with the memorandum by the Assistant Secretary of Defense for C^3I, Subject: National Imagery Transmission Format Standard (NITFS), 12 August 1991. This directive shall be implemented in accordance with the Joint Interoperability and Engineering Organization (JIEO) Circular 9008, NITFS Certification Test and Evaluation Program Plan, and the MIL-HDBK-1300A. New equipment and systems, those undergoing major modification, or those capable of rehabilitation shall conform to this standard.

1.4 Tailoring of task, method, or requirement specifications. The minimum compliance requirements for implementation of this compression algorithm are defined in JIEO Circular 9008.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplements thereto, cited in the solicitation.

FEDERAL STANDARDS

FED-STD-1037B	-	Telecommunications: Glossary of Telecommunication Terms, 3 June 1991.

(Copies of the referenced Federal Standards are available from General Services Administration, GSA Specification Section, Room 6654, 7th and D Streets, S.W. Washington, D.C. 20407; telephone (202) 472-2205).

MILITARY STANDARDS

MIL-STD-2500A	-	National Imagery Transmission Format (Version 2.0) for the National Imagery Transmission Format Standard, 18 June 1993.

MILITARY HANDBOOKS

MIL-HDBK-1300A	-	Military Handbook National Imagery Transmission Format Standard, 18 June 1993.

(Copies may be obtained from TASC, 55 Walkers Brook Drive, Reading, MA 01867-3297, Attn: NTB Secretary; telephone (617) 942-2000 x2932, fax (617) 942-7100).

2.1.2 Other Government documents, drawings, and publications. The following other Government documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation.

DISA/JIEO Circular 9008	-	National Imagery Transmission Format Standard Certification Test and Evaluation Program Plan, 30 June 1993.

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are Department of Defense (DoD) adopted are those listed in the issue of the DODISS cited in the solicitation.

INTERNATIONAL STANDARDS

ISO IS 10918-1/ CCITT Recommendation T.81	-	Digital Compression and Coding of Continuous-tone Still Images. Part I: Requirements and Guidelines, September, 1992.
ISO IS 10918-3/ CCITT Recommendation T.84	-	Digital Compression and Coding of Continuous-tone Still Images: Extensions, November, 1995.

(Copies may be obtained from X3 Secretariat, Computer and Business Equipment Manufacturers Association, 311 First Street NW, Suite 500, Washington, DC 20001-2178)

NATIONAL STANDARDS

None.

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence. Nothing in this standard, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS, ACRONYMS AND SYMBOLS

The following definitions are applicable for the purpose of this standard. In addition, terms used in this standard and defined in the FED-STD-1037B shall use the FED-STD-1037B definition unless noted.

3.1 Acronyms used in this standard.

a. JIEO Joint Interoperability and Engineering Organization (formerly JTC^{3}A)

b. JPEG Joint Photographic Experts Group

c. MCU Minimum Coded Unit

d. NITF National Imagery Transmission Format

e. NITFS National Imagery Transmission Format Standard

f. RGB Red, Green, Blue

3.2 Definitions used in this standard.

See IS 10918-1 for definition of terms used in this standard.

4. GENERAL REQUIREMENTS

4.1 Interoperability. The profile specified in this document is intended to enable the interchange in the NITFS format, of 2 to16 bit gray scale imagery and 24 bit color imagery. IS 10918-1 represents a collection of lossy and lossless compression techniques, a subset of the lossless procedures are used in generation of the compressed image data stream shown. Unless expressly forbidden in this profile, any procedure in IS 10918-1 applicable to lossless encoding may be applied. Any optional processes in IS 10918-1 required by this profile will be detailed.

FIGURE 1. NITF file structure.

4.2 Encoders. Encoders shall output to the image data field of the NITF file a full interchange format that includes the compressed image data and all table specifications used in the encoding process.

4.3 Decoders. All decoders shall interpret full interchange format. Abbreviated interchange format decoders are not a requirement of this profile.

4.4 Sample precision. The sample precision is specified to be from 2 to 16 bits for gray-scale and 24 bits for RGB color imagery.

4.5 Hierarchical processes. This profile does not allow usage of hierarchical lossless processes.

5. DETAILED REQUIREMENTS

5.1 Color space. The JPEG processes in IS 10918-1 are color blind. In this profile two types of imagery are specified, 2 to 16 bit gray scale and 24 bit RGB color. The IREP and IREPBAND fields (defined in MIL-STD-2500A) within the NITF image subheader are used to identify the color space for each component present in the image; these components may be interleaved or not. When the components are interleaved, the interleave order is R, G, B with each MCU containing three data units, one from each component. In the non-interleaved case, each MCU consists of just one data unit from any of the components.

5.2 Control procedures for the sequential lossless mode. The control procedures for encoding and decoding an image using this profile may be found in IS 10918-1. It is required by this profile that an NITF APP_6 application data segment be placed in the compressed data stream. This data segment immediately follows the first SOI marker in the Image Data Field (see Figure 1). The format and content of this data segment are discussed in section 5.3.5. This profile also requires the use of restart intervals for the purposes of error confinement and data resynchronization. Restart intervals are discussed in 5.3.1.4. NITF compressed imagery may include an optional APP_7 directory segment in the JPEG data stream, the format and content of this marker segment is discussed in 5.3.6.

5.2 Entropy encoder/decoder. IS 10918-1 defines two distinct entropy coders, Huffman and arithmetic. Huffman coding is required at this time and arithmetic coding is anticipated as a future requirement.

5.3 Format of a JPEG compressed image within an NITF file. The format for NITF image data compressed with the sequential lossless JPEG mode differs based on the number of blocks, bands, and IMODE value (B, P, S, see MIL-STD-2500A). These different cases are described below.

5.3.1 Single block JPEG compressed format. The format for NITF single block image data compressed with the sequential lossless JPEG mode is shown in Figure 2.

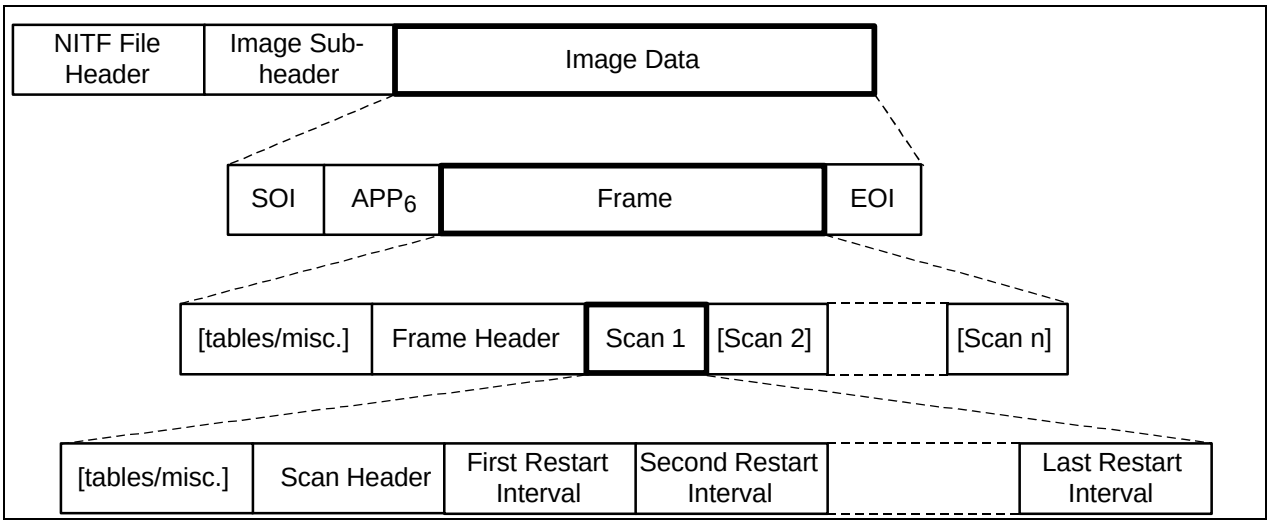

FIGURE 2. NITF single block file structure (IMODE=B or P).

5.3.1.1 Single block image data format. The top level of figure 2 specifies that the JPEG compressed data is contained in the Image Data Field of the NITF file. The second level of figure 2 specifies that the single block image format shall begin with an SOI marker, shall contain one frame, and shall end with an EOI marker. Between the SOI/EOI marker pair, the data stream is compliant with IS 10918-1 subject to the requirements and constraints of this profile.

5.3.1.2 Frame format. The third level of figure 2 specifies that a frame shall begin with a frame header and shall contain one or more scans. A frame header may be preceded by one or more table-specification or miscellaneous marker segments. NITF does not allow the use of the JPEG DNL segment which, when present, would follow the first scan in the frame.

5.3.1.3 Scan format. The fourth level of figure 2 specifies that a scan shall begin with a scan header and shall contain one or more restart intervals. A scan header may be preceded by one or more table-specification or miscellaneous marker segments. When the NITF image sub-header IMODE field is set to B, there shall be n scans within the frame, one for each of the components (n=1 or 3). When the IMODE field is set to P, there shall be a single scan within the frame consisting of three interleaved components.

5.3.1.4 Restart intervals. Following the scan header, each scan shall be encoded as a series of one or more restart intervals. A restart interval is a self-contained entropy-coded data segment that can be decoded independently from the other intervals. Restart intervals are used for error recovery (6.2). If the image were encoded as a single interval, then any transmission error would render all subsequent image data unusable. When several restart intervals are used, the effects of an error can be contained within a single interval. The restart interval is defined by the DRI marker as specified in IS 10918-1. In the IS restart intervals are optional, but NITF requires the use of restart marker codes with a restart interval which is a multiple of the number of MCUs per row and not exceeding a maximum of 8 sample rows. Byte alignment is achieved between restart intervals per IS 10918-1.

5.3.2 Multiple block JPEG compressed format. The format for NITF multiple block image data compressed with the sequential lossless JPEG mode is shown in Figure 3 for IMODE=B or P. The corresponding format when IMODE=S is shown in Figure 4**.**

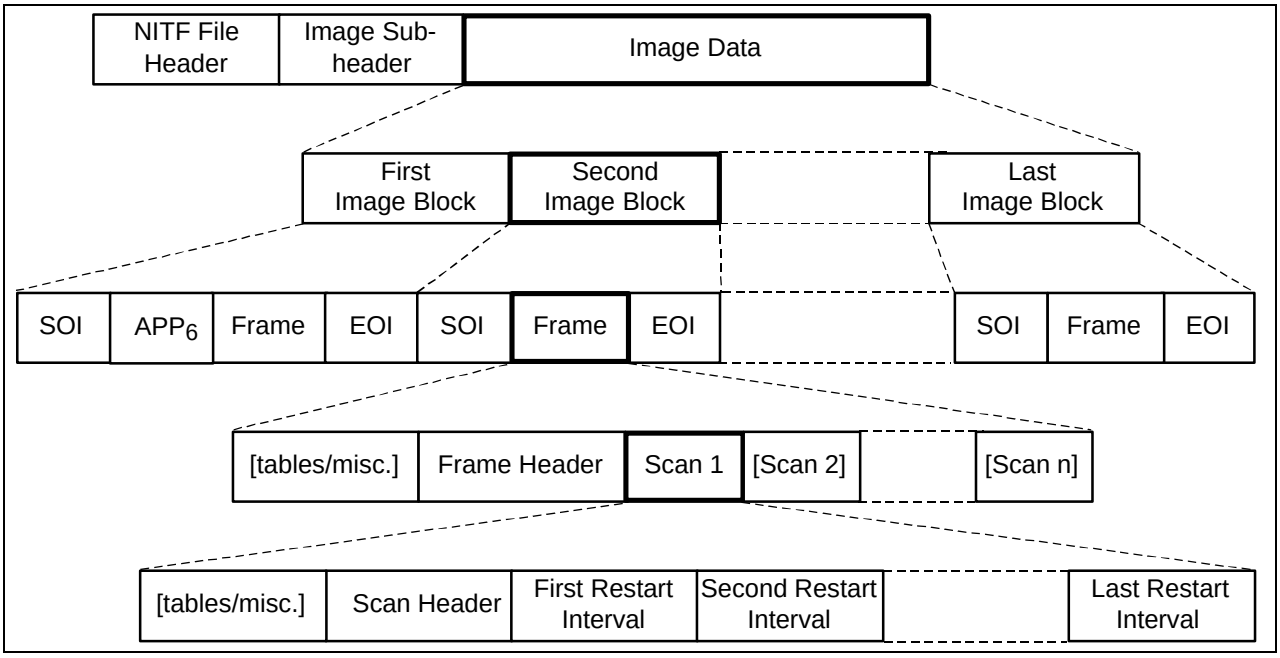

FIGURE 3. NITF multiple block file structure (IMODE=B or P).

5.3.2.1 Multiple block image data format (IMODE=B or P). The top level of figure 3 specifies that the JPEG compressed data is contained in the Image Data Field of the NITF file. The second level of figure 3 specifies that this multiple block image format shall begin with the compressed data for the first image block and shall be followed by the compressed data for each image block, one after the other, left to right, top to bottom. The third level of figure 3 specifies that each compressed block shall begin with an SOI marker, shall contain one frame, and shall end with an EOI marker. The format below this level is identical to the single block case previously described in 5.3.1.

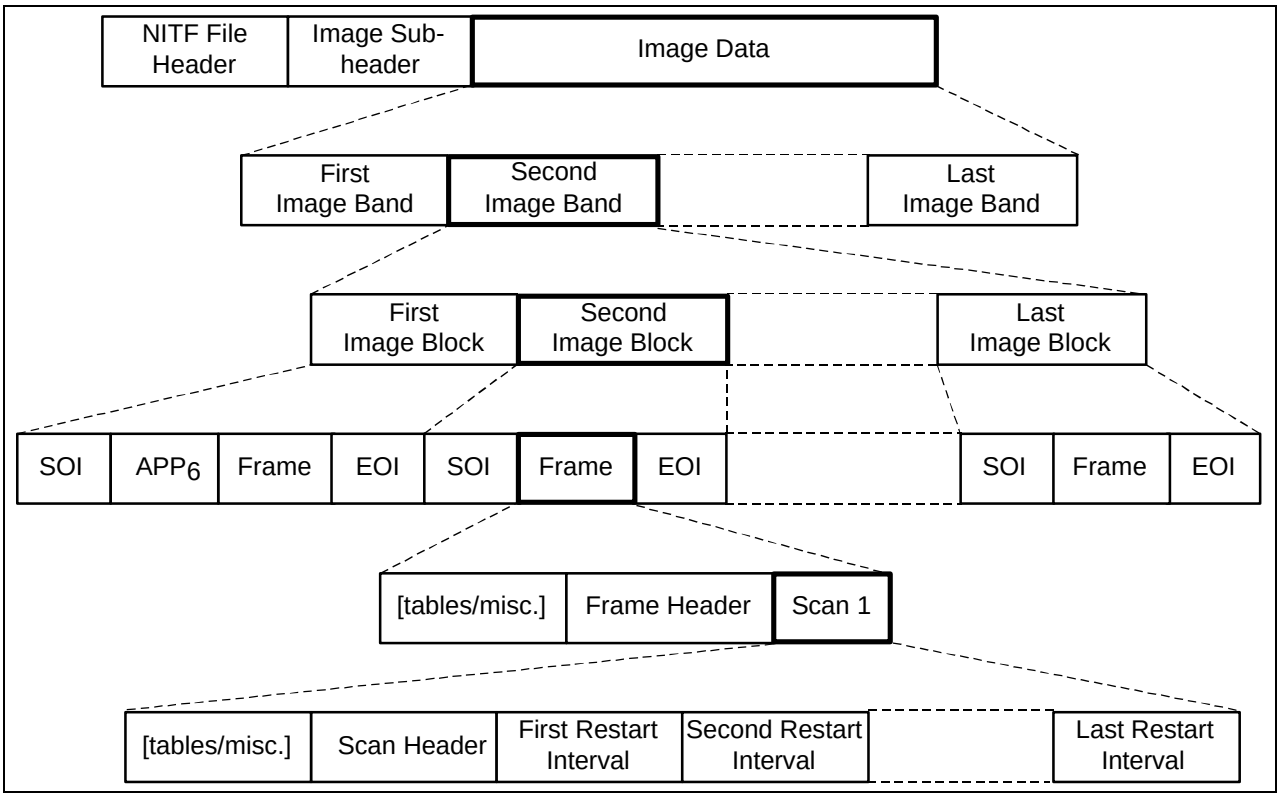

FIGURE 15. NITF multiple block file structure (IMODE=S).

5.3.2.2 Multiple block image data format (IMODE=S). The use of this IMODE requires that the image contain multiple blocks and multiple bands, otherwise IMODE shall be set to B or P. The top level of figure 15 specifies that the JPEG compressed data is contained in the Image Data Field of the NITF file. The second level of figure 15 specifies that this multiple block image format shall begin with the compressed data for the first image band and shall be followed by the compressed data for each image band, one after the other, first to last. The third level of figure 15 specifies that each compressed image band shall consist of the compressed data (for that band) for each image block, one after the other, left to right, top to bottom. The fourth level of figure 15 specifies that each compressed block shall begin with an SOI marker, shall contain one frame, and shall end with an EOI marker. The format below this level is identical to the single block case previously described in 5.3.3.1 with each frame containing only one scan that contains the compressed data from only one band.

5.3.2.3 Similarities with IS 10918-3 “simple tiling”. In IS 10918-3, extensions to the JPEG processes of IS 10918-1 are defined. One of these extensions deals with the tiling (blocked images in NITFS terminology) of images. Of the tiling formats present in IS 10918-3, simple tiling, is conceptually equivalent to the blocked image concept in NITF. It is important to note that the bitstreams generated by simple tiling in IS 10918-3 and blocked images in NITF are not compatible. In IS 10918-3 simple tiled images are treated as multiple frames within a single SOI/EOI marker pair. Image blocks in NITF are treated as separate images, each within their own SOI/EOI marker pair. Within the SOI/EOI marker pairs each

image block data stream conforms to IS 10918-1 subject to the requirements and constraints of this profile.

5.3.3 Frame header. The frame header specifies the source image characteristics, the components in the frame, and the sampling factors for each component which are constrained to be “no subsampling” for lossless JPEG, and selects the quantization table to be used with each component which is not applicable for lossless JPEG. The format is shown in Table I with variable fields specified in Table II for the different image types. Note that the field N_f may take on the values of 1 or 3 corresponding to gray-scale or 24 bit RGB imagery. The field Y may not take on the value 0 since the DNL segment is not allowed.

TABLE I. Frame header.

Offset	Field Value	Field Name	length (bytes)	comments	
0	0xFFC3	SOF_3	2	Start of frame. SOF_3 is used for "Spatial sequential lossless" with Huffman coding.	
2	see Table II	L_f	2	Length of parameters = $(8+3N_f)$	
4	see Table II	P	1	Sample precision	
5	1-65535	Y	2	Number of lines (note 0 is not allowed)	
7	1-65535	X	2	Number of samples per line	
9	see Table II	N_f	1	Number of components per frame, 1 or 3	
10	0	C_1	1	Component number = 0 (R)	
11	0x11	H_1V_1	1	Horizontal & vertical sampling factors (NA)	
12	0	TQ_1	1	Quantization table selector (NA)	
13	1	C_2	1	Component number = 1 (G)	if $N_f = 3$
14	0x11	H_2V_2	1	Horizontal & vertical sampling factors (NA)	if $N_f = 3$
15	0	TQ_2	1	Quantization table selector (NA)	if $N_f = 3$
16	2	C_3	1	Component number = 2 (B)	if $N_f = 3$
17	0x11	H_3V_3	1	Horizontal & vertical sampling factors (NA)	if $N_f = 3$
18	0	TQ_3	1	Quantization table selector (NA)	if $N_f = 3$

TABLE II. Variable frame header fields.

Field Name	gray scale	RGB color
L_f	11	17
P	2-16	8
N_f	1	3
C_1	0	0 (R)
C_2		1 (G)
C_3		2 (B)

5.3.4 Scan header. The scan header specifies which component(s) are contained in the scan and selects the entropy coding tables to be used with each component. IS 10918-1 allows usage of up to four Huffman tables with lossless processes. A single Huffman table is sufficient for gray scale and most RGB images. There may be certain instances where a unique Huffman table is desired for each RGB color component. This profile restricts the number of allowed Huffman tables to three for RGB images and one for gray scale. The Huffman table associated with a given image component is determined by Td_j, the DC entropy coding table selector. Allowed values for Td_j are [0, 1, 2], this is signified in Table III by 'X'. The variable fields of the scan header format are specified in Table III for the different image types. The format of the scan header may be found in the IS.

TABLE III. Variable scan header fields.

Field Name	gray scale	RGB color (interleaved)	RGB color (scan 1)	RGB color (scan 2)	RGB color (scan 3)
L_S	8	12	8	8	8
N_S	1	3	1	1	1
Cs_1	0	0 (R)	0 (R)	1 (G)	2 (B)
Td_1Ta_1	0x00	0xX0	0xX0	0xX0	0xX0
Cs_2		1 (G)			
Td_2Ta_2		0xX0			
Cs_3		2 (B)			
Td_3Ta_3		0xX0			

5.3.5 NITF APP_6 application data segment. NITF requires the use of an APP_6 application data segment. The NITF application data segment shall immediately follow the first SOI marker in the Image Data Field. The NITF application data segment contains information which is needed by an interpreter but not supported by the ISO/CCITT JPEG format. Most of this information is also present in some fields of the NITF image sub-header (COMRAT, IREPBAND, NBPP, etc.). Since no default Huffman tables are defined in this standard, the tables to be used by the decoder must always be present in the compressed stream. The Huffman table specification can optionally be embedded in the NITF application data segment. Multiple Huffman tables may be specified (up to three) in the application data segment. In this case the table(s) will provide “default” table specification(s) for subsequent image blocks. The DHT marker segment need not be embedded in the APP_6 data segment and may appear in the appropriate places in the bitstream as specified in the IS.

Only DHT marker segments embedded in APP_6 will be considered defaults. Huffman tables defined outside of APP_6 are considered “custom” tables. NITFS does not allow the carryover of custom Huffman tables from one image block to the next. Custom tables must be included in each block where default tables are not used. Any Huffman table defined with a previously used table identifier shall replace the previously defined table. The format is shown in Table IV with the Huffman table segment variable fields specified in Table V for the different image types.

TABLE IV. NITF APP_6 application data segment.

Offset	Field Value	Field Name	length (bytes)	comments	
0	0xFFE6	APP_6	2	NITF application data marker.	
2	see table V	L_p	2	Segment length (2+length of application data)	
4	0x4E49 0x5446 0x00	Identifier	5	Null terminated string: "NITF"	
9	0x0200	Version	2	Version number. The most significant byte is used for major revisions, the least significant byte for minor revisions. Version 2.00 is the current revision level.	
11	0x42, 0x50 or 0x53	IMODE	1	Image Format. Three values are defined at this time. 'B' - IMODE=B 'P' - IMODE=P 'S' - IMODE=S	
12	1-9999	H	2	Number of image blocks per row.	
14	1-9999	V	2	Number of image blocks per column.	
16	0-1	Image Color	1	Original image color representation. Two values are defined at this time. 0 - monochrome 1 - RGB	
17	1-16	Image Bits	1	Original image sample precision.	
18	0-99	Image Class	1	Image data class (0-99). One value is defined at this time 0 - general purpose	
19	1 - 29	JPEG Process	1	JPEG coding process. The values for this field are defined to be consistent with ISO IS 10918-2. 14 - Sequential lossless	
20	0xFFC4	DHT	2	Define Huffman table marker	
22	see table V	L_h	2	Length of parameters	
24	see table V	T_cT_h	1	T_c: Table class = 0 T_h: Huffman table identifier (0-2).	first table
25	0-255	L_i	16	Number of codes of each length (BITS array)	first table
41	0-255	$V_{i,j}$	see Table V	Symbols (HUFFVAL array)	first table
	see table XII	T_cT_h	1	T_c: Table class = 0 T_h: Huffman table identifier (0-2).	last table

	0-255	L_i	16	Number of codes of each length (BITS array)	last table
	0-255	$V_{i,j}$	see Table V	Symbols (HUFFVAL array)	last table
		Flags	2	Reserved for future use.	

TABLE V. Variable DHT fields.

Field Name	N-bit gray scale N∈ [2, 3, …, 15]	16-bit gray scale	RGB color (N = 8)	
Lp	$22 + L_h$	58	$22 + L_h$	
L_h	$19 + m_t$	36	$2 + \sum_{t=1}^{n} (17 + m_t)$	
$T_C T_h$	0x00	0x00	0x0X, X∈ [0, 1, 2]	
# of $V_{i,j}$ (m_t)	$m_t = N + 1$	17	$m_t = 9$	Predictors 1-3 and 7
	$m_t = N + 2$	17	$m_t = 10$	Predictors 4-6

5.3.6 NITF APP_7 directory segment. NITF applications may use an APP_7 directory segment. The NITF APP_7 directory segments are used to provide random access to the variable length compressed data segments. APP_7 segments contain a directory of offset information for a series of scans or restart intervals depending on the directory type. In all cases, offsets are measured from the beginning of the Image Data Field in the NITF file to the beginning of the element. The number of entries depends on the directory type and is the number of (restart intervals per scan) or (scans per block) for directory types: 'R' and 'S', respectively. The format for APP_7 is shown in Table VI. The number of directory entries can be very large for restart interval directories. In these cases it is possible for a directory to exceed the, ≈ 64 kbyte, segment limitation imposed by the 2 byte L_p field offset in any JPEG application data segment. Since each element requires 4 bytes in the directory, this translates to a maximum of 16, 382 entries.

When a logical directory contains more than 16,382 elements, they must be split between more than one directory. In this case, multiple APP_7 directory segments must follow each other with no other intervening data and they must be of the same directory type (restart interval). Each additional APP_7 directory contains those elements, in the same order, that would have been present in the directory had there been no size limitation. Another mechanism called, blocked image masking, may be used in the NITF data format to provide direct access to image blocks, in the same spirit that APP_7 provides access to entropy coded data. Blocked image masking requires the use of an image data mask subheader in the NITF file. The content, structure and use of block image masking may be found in MIL-STD-2500A.

TABLE VI. NITF APP_7 directory segments.

Offset	Field Value	Field Name	length (bytes)	comments
0	0xFFE7	APP_7	2	NITF directory segment marker.
2	4N + 5	L_p	2	Segment length (2 + length of application data).
4	0x52, 0x53	Directory Type	1	Directory type. Two values are defined at this time. 'R' - Restart Interval Directory 'S' - Scan Directory
5	1-16382	N	2	Number of directory entries. Note 0 is not allowed. Maximum value of N (16,382) maximizes L_p at 65533.
7		1^{st} Offset	4	Offset to first element in this directory (restart interval, scan).
11		2^{nd} Offset	4	Offset to second element in this directory.
4N + 3		Last Offset	4	Offset to last element in this directory.

6. NOTES

(This section contains general or explanatory information that may be helpful but is not mandatory).

6.1 Critical data. The JPEG marker segments (frame header, scan header, DHT, DRI, APP_6) are critical data. Corruption will result if these data are lost.

6.2 Use of restart intervals. Restart intervals introduce some overhead into the data stream to provide a level of error protection. A "smart decoder" will detect a transmission error as an invalid data stream during the decoding process and then skip forward looking for the next restart marker code to resynchronize. There is a tradeoff between the amount of overhead and the level of protection obtained. Neglecting the effects of packet size and error handling in the communications protocol, errors can be contained to a single restart interval. The overhead introduced by each restart interval is 20 bits on average for Huffman coding.

APPENDIX A

HUFFMAN TABLES

10. Scope. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance.

20. Applicable documents. This section is not applicable to this appendix.

30. Default Huffman tables. No default Huffman tables are provided.

40. Specification and generation of Huffman tables. See ISO IS 10918-1.

STANDARDIZATION DOCUMENT IMPROVEMENT

(See Instructions - Reverse Side)

1. DOCUMENT NUMBER U-321/CIO-2 MIL-STD-188-XXX	2. DOCUMENT TITLE Joint Photographic Experts Group (JPEG) Lossless Image Compression for the NITFS

3a. NAME OF SUBMITTING ORGANIZATION b. ADDRESS *(Street, City, State, ZIP Code)*	4. TYPE OF ORGANIZATION *(Mark one)* ☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER *(Specify):* _____

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI) - Optional*	b. WORK TELEPHONE NUMBER *(Include Area Code) - Optional*
c. MAILING ADDRESS *(Street, City, State, ZIP Code) - Optional*	8. DATE OF SUBMISSION *(YYMMDD)*

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